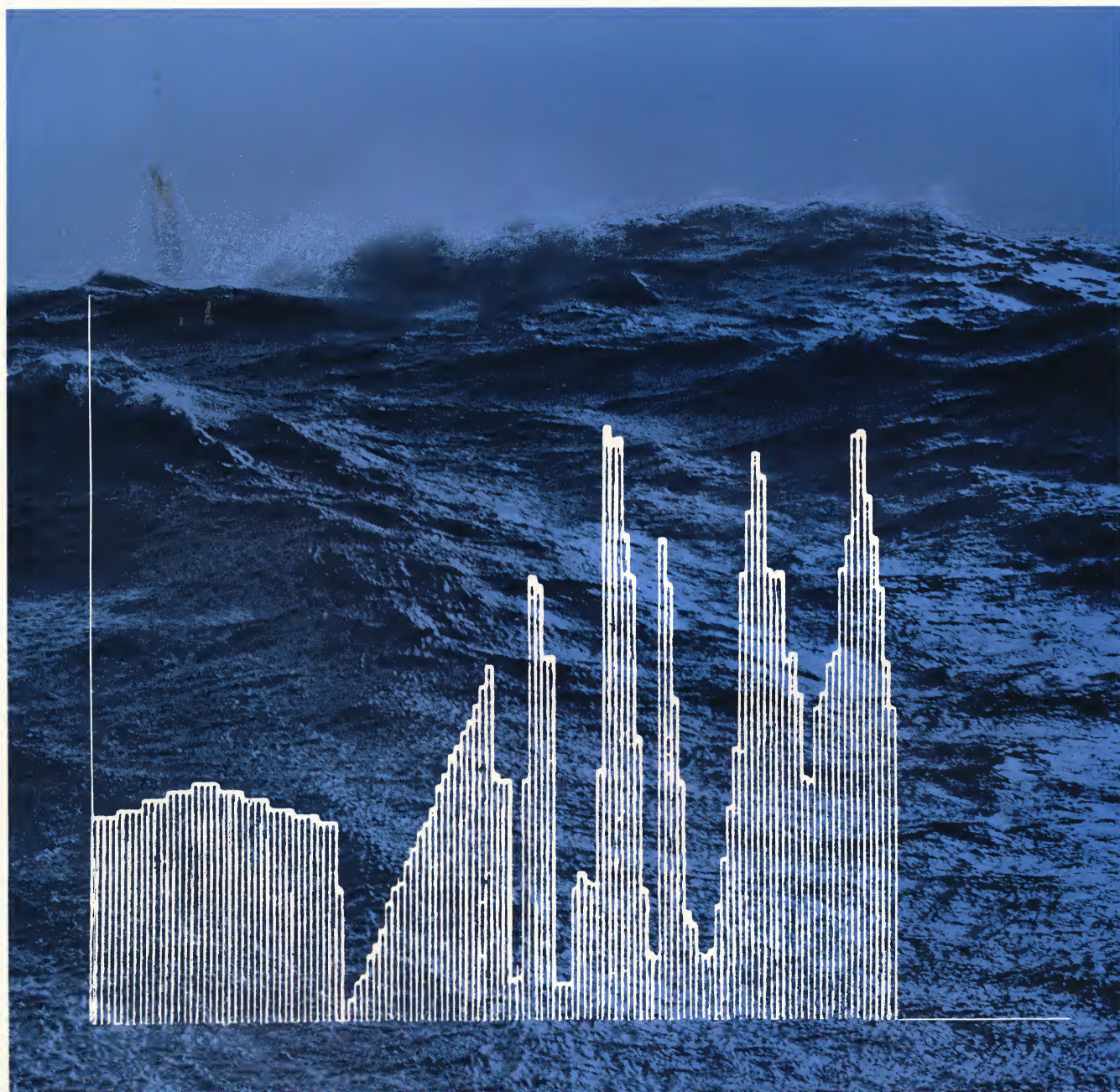
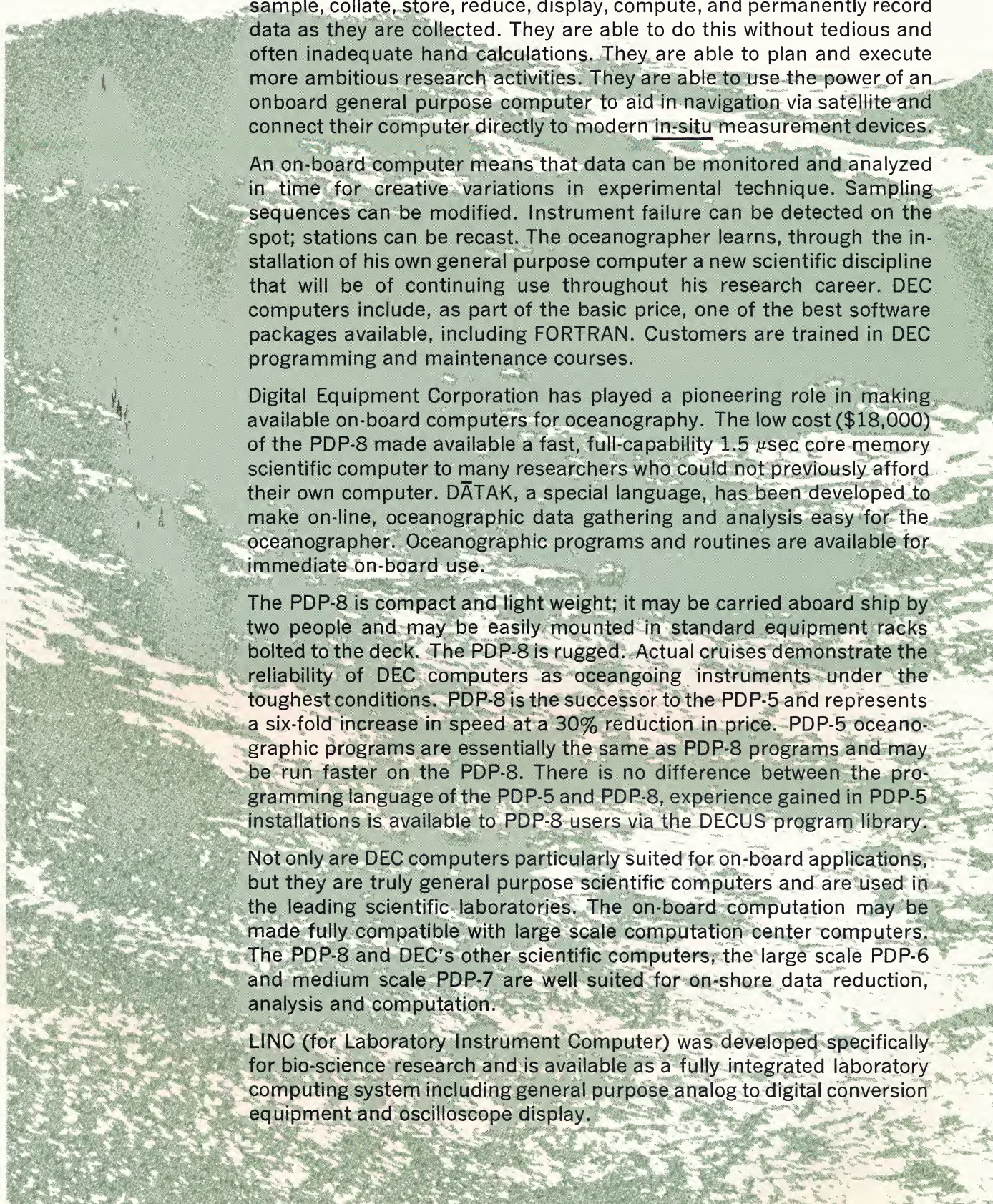




COMPUTERS IN OCEANOGRAPHY



DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS



That the general purpose computer can be an effective tool in dealing with the data gathered on oceanographic surveys is no new story. Nor is the power of the computer for use as a navigation aid. What is new, is that more and more oceanographers are learning to use computers on-board — as personal research instruments. Researchers are able to sample, collate, store, reduce, display, compute, and permanently record data as they are collected. They are able to do this without tedious and often inadequate hand calculations. They are able to plan and execute more ambitious research activities. They are able to use the power of an onboard general purpose computer to aid in navigation via satellite and connect their computer directly to modern in-situ measurement devices.

An on-board computer means that data can be monitored and analyzed in time for creative variations in experimental technique. Sampling sequences can be modified. Instrument failure can be detected on the spot; stations can be recast. The oceanographer learns, through the installation of his own general purpose computer a new scientific discipline that will be of continuing use throughout his research career. DEC computers include, as part of the basic price, one of the best software packages available, including FORTRAN. Customers are trained in DEC programming and maintenance courses.

Digital Equipment Corporation has played a pioneering role in making available on-board computers for oceanography. The low cost (\$18,000) of the PDP-8 made available a fast, full-capability 1.5 μ sec core memory scientific computer to many researchers who could not previously afford their own computer. DĀTAK, a special language, has been developed to make on-line, oceanographic data gathering and analysis easy for the oceanographer. Oceanographic programs and routines are available for immediate on-board use.

The PDP-8 is compact and light weight; it may be carried aboard ship by two people and may be easily mounted in standard equipment racks bolted to the deck. The PDP-8 is rugged. Actual cruises demonstrate the reliability of DEC computers as oceangoing instruments under the toughest conditions. PDP-8 is the successor to the PDP-5 and represents a six-fold increase in speed at a 30% reduction in price. PDP-5 oceanographic programs are essentially the same as PDP-8 programs and may be run faster on the PDP-8. There is no difference between the programming language of the PDP-5 and PDP-8, experience gained in PDP-5 installations is available to PDP-8 users via the DECUS program library.

Not only are DEC computers particularly suited for on-board applications, but they are truly general purpose scientific computers and are used in the leading scientific laboratories. The on-board computation may be made fully compatible with large scale computation center computers. The PDP-8 and DEC's other scientific computers, the large scale PDP-6 and medium scale PDP-7 are well suited for on-shore data reduction, analysis and computation.

LINC (for Laboratory Instrument Computer) was developed specifically for bio-science research and is available as a fully integrated laboratory computing system including general purpose analog to digital conversion equipment and oscilloscope display.



Atlantis II



Evergreen



ATLANTIS-II

The Atlantis II left Woods Hole on January 21, 1965 for a round the world expedition. The Indian Ocean phase of the voyage is part of a 23 nation experiment sponsored by UNESCO, in an effort to help the poverty-stricken nations of the Middle East increase their food supply by using the resources of the Indian Ocean. The 50,000 mile voyage included the following ports of call: Port Said; Bombay; the Serphelles Island; Fremantle, Australia, and Tokyo.

In addition to the UNESCO phase of the cruise, the Atlantis II collected hydrographic information used to chart currents, and geological information.

The Digital Equipment Corporation PDP-5 computer is being used around the clock for satellite navigation, hydrographic station data reduction, cruise data storage and retrieval, display of oceanographic data, analog to digital conversion and a variety of general purpose computational tasks. "The use of the computer as a real-time oceanographic tool has permitted us to make decisions on the basis of information that would not have been available otherwise. A large part of the scientific portion of the cruise has depended on computer-produced results," stated Atlantis II scientific personnel.

"The future course of computers at sea is limited more by the imagination of oceanographers in structuring questions than by the hardware available," stated Atlantis researchers.

EVERGREEN

From March to August the Evergreen participates in the International Ice Patrol season. The Evergreen's patrol consists of an oceanographic survey of the Grand Banks and Labrador Sea in March and April.



Aboard Atlantis II

USCG's oceanographic surveys in the vicinity of the Grand Banks are used principally for predicting the course and speed of sea ice and icebergs. It is mandatory that collected data be worked up as soon as possible.

Following a preliminary one-week evaluation while the Evergreen was engaged in search and rescue duties in the vicinity of Georges Bank and Cultivator Shoals of Massachusetts, the PDP-5 was used to process data tasks for about 500 oceanographic stations. About 400 casts of 13-to-18 bottles each were made for temperature and salinity down to 1,500 meters. In another 100 casts of 18-to-28 bottles each to 4,000 meters, oxygen determinations were also made. The DEC computer was used to record the data and make standard integration and scaling calculations for the determination of Sigma-T and Delta for standard depths. Not only did the computer show gains in the speed reliability, and precision with which data could be evaluated, but used on-line, it provided an immediate in situ check of instrumentation performance.

Specific comparisons show the speed advantages of machine over hand processing. Hand processing of the data for just one 13-bottle station takes about three hours, including corrective reversing thermometers, transcribing information, determining Sigma-T and the anomaly of specific volume, scaling for standard depth, calculating dynamic heights, and checking. Using the computer, these same procedures take about 15 minutes.

The computer was placed on board and installed in less than two hours and with relative ease. A small crane was used to hoist it aboard and lower it through a small hatch to the main deck. Its 390-pound weight created no problem, and since it was on casters it was readily wheeled down the narrow passageway to the oceanographic laboratory. Disregarding shock mounting, the computer was bolted directly to the deck — which happened to be right over the ship's main boiler. An ASR-33 typewriter input/output unit was mounted in a similar manner directly adjacent to the computer. The computer was then plugged into a standard 110-volt AC power outlet and turned on. The memory of this computer is non-destructive and the machine was able to perform the test routine that had been put in at the factory. On the 1964 computer evaluation cruise, winds often approached Beaufort scale 11, Sea State 9. At one point the ship rolled through 102° in six seconds.

While Evergreen was patrolling off Massachusetts, the following tests were performed — with no adverse effects on the computer's operation.

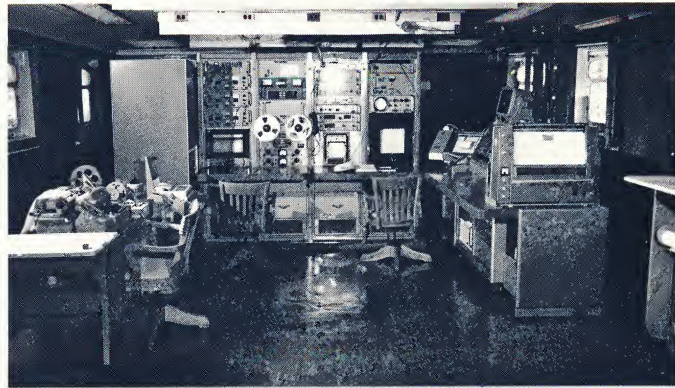
Line frequency was deliberately lowered and raised between 58 and 62 cps while the computer was operating.



Pierce



Brown Bear



Hudson Installation

Line voltage dropped to approximately 80 volts when heavy deck machinery was used.

Degaussing was employed in order to cancel the magnetic signature characteristics of the vessel.

Ship's radar and radio transmitters were used repeatedly with no ill effects, even though the antennas were comparatively close by.

Due to the inherent harmonics of a Diesel-electric power system, the ship vibrates constantly while underway. Again, no ill effects.

The computer was operated normally in a temperature range of 45°-to-90° without difficulty.

The only formal training received by Coast Guard personnel in the operation and maintenance of the computer was a one-week programming class and a two-week maintenance course conducted by Digital Equipment Corporation.

PIERCE

From the middle of March, 1965 to the end of July a PDP-5 computer was used solely to compute the position of the Pierce while the ship was engaged in hydrographic surveys. In July the computer was also harnessed to the task of on-line data processing and will continue to be used for both of these applications.

The Pierce's task consists of taking bathythermographs and Nansen bottle casts at specified locations in the Gulf Stream — part of a year-long Gulf Stream study being coordinated by the Coast and Geodetic Survey of the Environmental Science Service Administration. The computer programs used in this project consist of a temperature correction program. One of the programs corrected thermometer readings and determined the thermometric depths. Another program computed the specific volume and dynamic height from data obtained from a nansen bottle cast.

Two programs were used to determine the ship's position. The first program was used to convert hyperbolic lane count values obtained from a Decca Hi-Fix system to X-Y rectangular coordinates. This enabled the ship to easily plot its position while underway conducting a hydrographic survey. The manner in which this was performed was by the computer operator typing in the lane count on the ASR-33 values obtained from the Hi-Fix receiver. The computer then typed out on the same line the corresponding X/Y rectangular coordinates.

The second program was used to compute a hyperbolic lane count value from a three point fix. This was necessary in order to calibrate the Hi-Fix dials since the Hi-Fix system

only measures a fraction of a lane (up to approximately 87 meters) and the lanes themselves must be counted through a mechanical linkage on the Hi-Fix receiver. Thus when first starting to use the system or when an interruption occurs because of static, equipment failure, etc., a lane count value must be determined so as to correctly initialize the Hi-Fix dial readings. This program used sextant angles that were sighted on three known signal locations and whose X-Y coordinates were known.

This program then computed the ship's position in X-Y coordinates and further translated them to hyperbolic lane count values. These computed values were then compared to the lane count values taken and recorded simultaneously with the sextant angles; which thus lead to a correction that could be applied to the dial readings so as to obtain the correct dial setting.

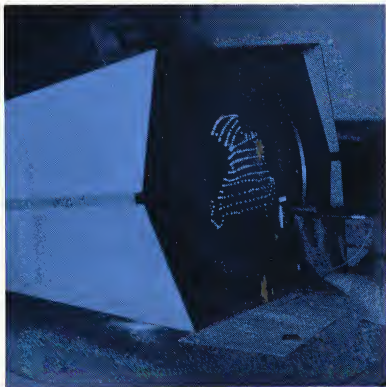
BROWN BEAR

Last year the Brown Bear research vessel manned by University of Washington oceanographers used the PDP-5 computer for an expedition to collect physical and chemical and biophysical data which was obtained 800 miles off the coasts of Oregon, Washington and British Columbia. Previously, the data obtained on missions of this sort couldn't be processed until after the vessel returned to shore. By obtaining preliminary computations while at sea, the oceanographers were able to evaluate findings immediately and make changes in the cruise plan while underway.

HUDSON

A PDP-5 computer was installed aboard CSS Hudson by the Bedford Institute of Oceanography for trial and evaluation of the computer in processing the output from a geophysical data logging system. The ship sailed from Halifax March 8 and returned May 1, 1965. During this period two cross sections were run across the Atlantic and systematic surveys were run in a section of the Median Valley of the Mid-Atlantic Ridge and the Western Approaches to the United Kingdom.

The ship steamed approximately 12,000 nautical miles and during this period 3.3 million decimal digits of positional and geophysical data were logged automatically on 28,000 feet of one-inch, eight-level paper tape. Data logging of time, gravity and magnetics was accomplished by an off-line geophysical data logging system (GEODAL) developed by the Bedford Institute of Oceanography. When the ship was in range of a Decca Navigational System, deccometer readings were digitized and stored on the punched paper



Information International

tape. The tape was then used as an input to the computer.

On previous cruises, calculations were performed from the same basic system with seagoing personnel and desk calculators. Corrections were applied to the gravimeter readings for time lag, east-west component and absolute value of the ship's velocity. The latter corrections were established by computing the position of the ship from the Decca coordinates and velocity from successive positions and times. While at sea, a total of 522 hours of computer time was used for these calculations. The PDP-5 reliably handled the geophysical data with an increase in speed and flexibility.

Future plans for the shipborne system includes the use of a high speed paper tape and a Calcomp plotter. With these facilities it is likely that additional oceanographic parameters will be logged on future cruises of the ships from the Bedford Institute of Oceanography.

INFORMATION INTERNATIONAL

Information International Inc. is currently using DEC computers for automatic reading and analysis of Oceanographic film records with a fully automatic film reading system, known as a Programmable Film Reader. The system which uses a PDP-7 digital computer is able to scan and recognize a variety of scientific data recorded on film.

For several years, Information International has been using the Programmable Film Reading System to read and analyze data recorded on film by oceanographic current meters, under contract to the Woods Hole Oceanographic Institute, the U.S. Public Health Service, and similar activities. Current meters contain devices for automatically recording on film the direction and rate of flow of ocean or fresh water currents. Data is recorded on the film in the form of interrupted lines or bars. This data can be automatically scanned and analyzed by the film reading system. Output is recorded on magnetic tape; it consists of a digital transcription of the original data recorded on the film.

Oceanographic bathythermographs are used to record on film or similar media the temperatures of ocean water at various depths. These data are recorded in the form of a line or trace across a slightly curved grid coordinate system. Reading of large quantities of these traces by hand has been a tiresome and expensive process. The I.I.I. Programmable Film Reader System makes it possible to rapidly and automatically read and digitize these traces, at a rate far greater than human operators can achieve.

Another I.I.I. use of PDP-computers for oceanographic research is the World Oceanographic Data Display System.



The System is based on the use of a PDP digital computer with type 30 display, to enable a researcher to conduct an analysis of oceanographic data using a series of visual displays generated by a digital computer. The eventual goal of the program will be the design of a computer system capable of storing the entire body of world oceanographic data and making it available for visual display and analysis.

The researcher will be able to select specific data for display, in the form of contour lines against a map of a selected oceanic area. He will be able to vary the parameters of the data selected, and observe the resulting variations in the contour lines. It is anticipated that the world oceanographic data display system will open up the presently available body of oceanographic data to a rapid and meaningful analysis by oceanographic researchers.

A third oceanographic application for DEC computers at I.I.I. is the Vortex Ocean Model Program. This program also uses a DEC CRT Display and enables an oceanographic researcher to simulate the interaction of ocean vortices on the scope face. The researcher can control the configuration of the vortex simulation by appropriate data entries made by means of a typewriter connected to the computer. The value of any of the variables in the simulation may be changed at any time in this way during the course of the simulation. The number of vortices may be varied from one to thirty-one. Vortices may interact in either a circular or an unbounded ocean.

COMPUTER-PLOTTING SYSTEM

A PDP-8 computer coupled with a large flat-bed X-Y plotter will be used for precise Hydrographic Surveys. Coastal Charts that show bottom topography and specific sounding will be constructed from the information that is collected through this shipboard computer.

Geographic position information will be automatically introduced by one of the presently available precise systems for coastal hydrography. Soundings and other information, such as the Julian date and draft of the ship, will also be introduced directly to the computer. The computer will then automatically plot the course and soundings of the ship on the X-Y plotter and compare it against the desired projected track. Indicators sent to the helmsman from the computer will tell him if he is off the track and how to correct in order to place the ship back on the correct track.

In addition to the above, the computer will be used as a general purpose machine for a variety of hydrographic and oceanographic applications. Some of these applications will be plotting three position sextant angle fixes, and solving problems in geodesy.

PROGRAMMING AND INTERFACING A COMPUTER FOR OCEANOGRAPHIC APPLICATIONS WITH DATAK

DATAK is a programming aid which allows the oceanographer to format his data acquisition requirements in a simple language similar to algebra. It gives him a great deal of flexibility in choosing interface hardware. DATAK programs also allow him flexibility in choosing the frequency and conditions under which he samples the experimental environment as well as making it possible to add or change sensors without major reprogramming the computer. DATAK is currently available for the PDP-8.

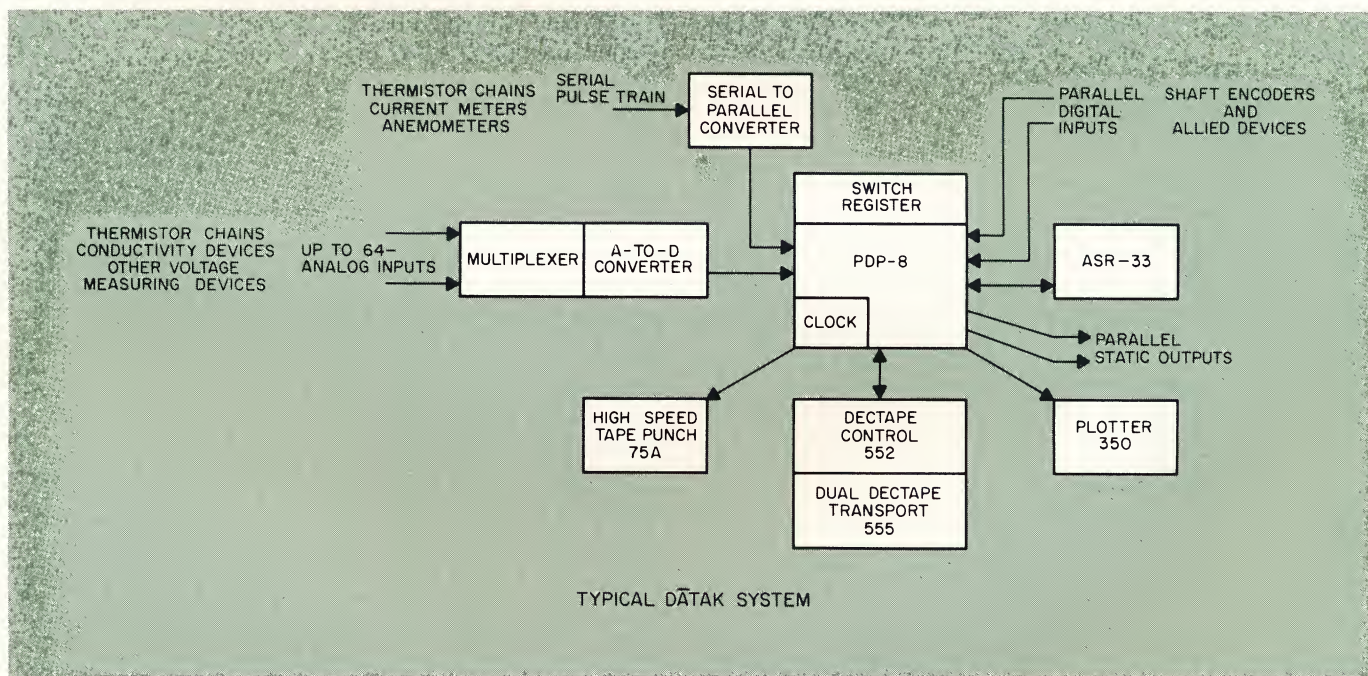
Special hardware buffers are available for each of the three kinds of data input which allow data from environmental sensors to enter the computer under control of the DATAK program. Data can come to the computer from digital-parallel inputs, serial inputs, and the multiplexed analog-digital inputs. DATAK gives the oceanographer the following flexibility when sampling the environment:

1. A variety of preprogrammed interface devices easily

connect computer directly to instrumentation.

2. Simple symbolic assignment of identifying names to physical input variables such as "Pressure," "Temperature."
3. Absolute control in sampling the experimental environment with respect to time.
4. Computer compatibility with respect to rapid response sensors using up to 176 separate sensing devices.
5. Capability to make logical decisions concerning the acquisition of data while sampling the environment.
6. Storage of data for future computations, as well as immediate output, for checking quality while obtaining data.

DATAK allows the investigator to analyze his sample using the following inputs.





Up to 96 independent data variables using digital-parallel input.

Up to 64 independent data variables using a multiplexed A-to-D converter.

Up to 25 independent data variables via serial buffer input.

Each independent variable can be sampled at a rate of up to 100 times per second.

Data output can be distributed to a number of devices to allow immediate presentation as well as permanent storage. The following devices are available:

1. On-line teleprinter. Variables can be typed in decimal or octal.
2. High-speed paper tape punch. Variables can be punched in decimal or octal.
3. Digital's compact DECTape. Variables are recorded magnetically on DECTape in binary with identifying words.
4. X-Y plotter. The plotter pen is moved to a new position each time an output is specified.

Up to four digital outputs are available through parallel buffers to other devices such as relays, buffers, sense lines, and range switching devices.

AVAILABLE OCEANOGRAPHIC PROGRAMS

Oceanographic programs have been written for the PDP-8 which provide the oceanographer with a means of record-

ing pertinent surface environmental phenomena as well as recording subsurface values of temperature and salinity. These programs are ready to use. They allow easy transfer of data to standard NODC forms for transmission to the National Oceanographic Data Center.

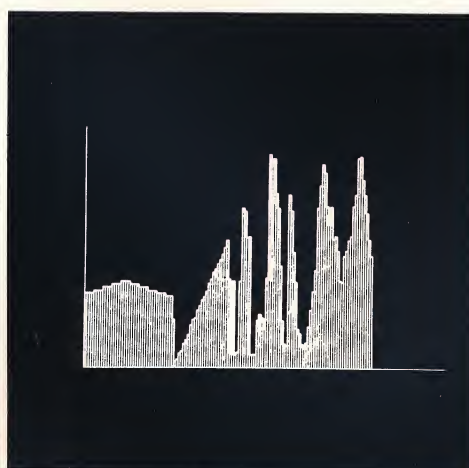
One program computes Sigma T, the anomaly of specific volume and sound velocity for each observed sample depth; allowing the oceanographer to examine the stability of the water mass prior to further computation. When the computer has calculated the last observed anomaly of specific volume, it proceeds to a scaled value format in which the oceanographer can scale temperature and salinity at any desired depth between observed data points.

Since there are two distinct interpolations using the observed values (two above, one below the desired scaled value and one above, two below the desired scaled value) there are two values each of temperature and salinity that are scaled. The average of the two interpolated values is also calculated, resulting in a total of three values each of temperature and salinity. The oceanographer then chooses one of the calculated scaled values for temperature and one for salinity and the computer determines Sigma-T and the anomaly of specific volume for the chosen values.

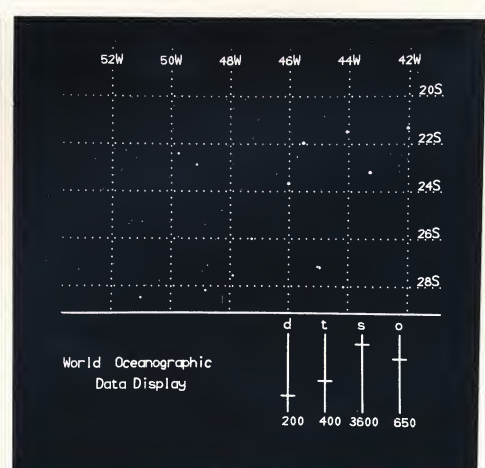
In addition, the varied oceanographic programs that have been written and are being written by DEC computer users are available through DECUS, the Digital Equipment Corporation Users Society.



Mathematical Vortex Ocean Model Generated and Displayed on DEC Computers



Histogram of Ocean Current Speed Read From Film and Displayed on DEC Computers



Computer Library System of Retrieving and Displaying Oceanographic Station Data

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